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Introduction to ST7 Concept Areas

Autonomy and On-Board Processing

Rick Schnurr

NASA Goddard Space Flight Center

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Objectives

2.1 <u>Concept Objectives</u>. The main objectives of the validation flight are:

- Demonstrate capability for opportunistic science by implementing a fast sense-decide-act loop integrating spacecraft subsystems and on-board science data processing. Perform a near real-time science data analysis and combine the results with the goal-oriented ground commands to drive the mission's execution

- Demonstrate reduced operations cost resulting from using autonomous planning, scheduling, and execution

ST7 TA Preproposal Conference

Autonomy and On Board Processing Architecture

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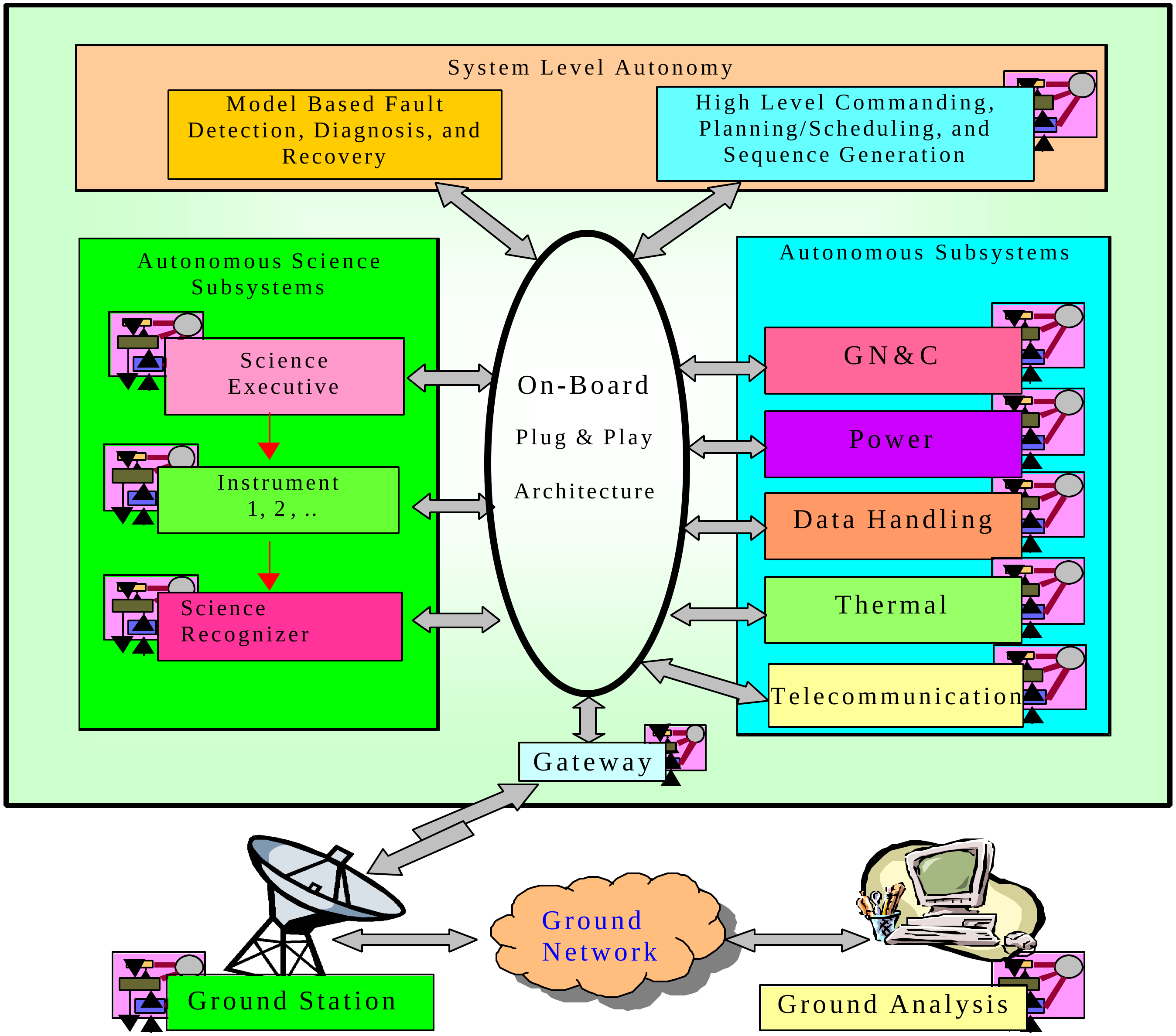

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Software Environment

2.3. <u>Software Integration.</u> The on-board architecture for this flight validation experiment will not be constrained to any prior software architecture – the integration, performed by the Study Team, will use standard modeling languages and open standards like: UML, XML, Posix, IP, JAVA.

•Autonomy software architecture will be modular in nature to allow future missions to easily adopt the results of this validation experiment in whole or in part

•The networked subsystems are expected to behave as peers with each sub-system having its own autonomy component for local control

•The spacecraft's architecture will coordinate the cooperation between the subsystem components and other space assets in hierarchic manner

•Autonomy components will be separable to allow independent development, modeling and testing

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Software Environment (Cont)

- Extendability and maintainability of the autonomy components will be of prime importance
- The flight validation experiment will be compatible with the use of "Open Source operating systems" such as Linux and RTIMS
- The flight validation experiment will have an advanced on-board file system that is distributed across the network. "Files" will be moved across the network. The system shall have the capability to reliably deliver these files to the ground. The file system shall be accessible via standard networking methods
- Science processing and autonomy software will be able to direct the mission as well as control the science instrument.
- The autonomy software shall be capable of accepting high level commands as well as direction from the science autonomy components provided by different investigators.

3.1 <u>Technology Needs</u>. The advanced technologies needed for the ST7 Autonomous and On-Board Processing flight validation experiment include:

a. **On-board Science Processing Software** capable of detecting key phenomena to determine new observation opportunities, modifying current observation sequences, as well as prioritizing data for downlink.

b. **System-level Autonomy Software** for coordinating subsystems to support High-Level Commanding, Planning/Scheduling, and Sequence generation for collaboration with ground and other space asset in hierarchic manner.

c**. System-level Autonomy Enabler** for model-based fault detection, diagnosis, and recovery.

d. **Advanced Autonomy Enabler for Subsystems** including Attitude Control, Power, Thermal, and Data Management. Automatic reliable data delivery (including automatic communications scheduling directed by on-board resources) subsystems.

e. **Hardware Concepts** for on-board data processing with high-capacity for on-board computing**.**

A hierarchy of autonomy enablers at the system level, the observation level, and the individual instruments and subsystem is envisioned. Each autonomy enabler accepts high-level goals and commands and decomposes them ultimately into sequences to accomplish the goals. It utilizes models of the system including resources, states, flight rules and constraints, and autonomy technology elements to obtain a conflict-free solution. A representative architecture of the autonomy enabler is shown in Figure A2.2.

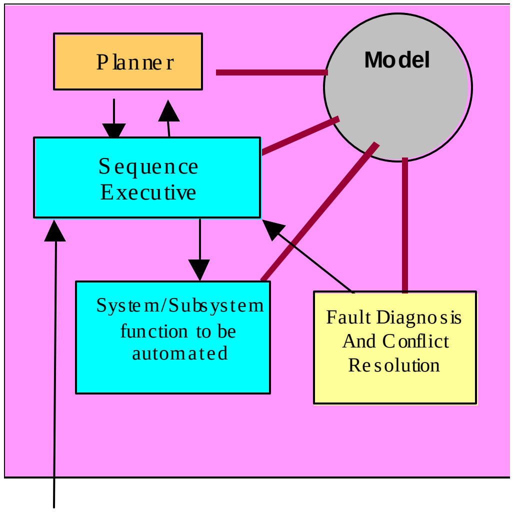

Figure A2-2: Autonomy Enabler Functions

Proposals from teams that include **autonomy technologists** as well as **spacecraft subsystem engineers (or instrument scientists)** are encouraged. Proposers should consider capability and efficiency metrics in delivering their concepts. While capability metrics depend on the autonomy software element, several efficiency metrics apply to all subsystems. **These efficiency metrics include the on-board resources in terms of memory, computation, and communication bandwidth needs**. Preferred technologies will require less memory, fewer computation, and less communication bandwidth.

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4.0 Technology Selection Opportunities and Planned Funding Levels

The planned number of technology provider opportunities and funding for the Study Phase is indicated in Table A2-1.

Table A2-1: Concept Definition Study Phase Award Levels

Technology Area	Opportunities	Funding
On-board Science Processing Software	2	$50,000 each
System-Level Autonomy Software	2	$50,000 each
System-Level Autonomy Enabler for model-based fault detection, diagnosis, and recovery software	2	$50,000 each
Advanced Autonomy Enabler for subsystems	4	$50,000 each
Hardware concepts supporting breakthrough on-board science processing	2	$50,000 each

a. **On-Board Science Processing Software**. This software includes a science executive with a local instrument controller and a science recognizer (defined in Section 3.2 a. (2) below).

(1) Science Executive with Local Instrument Controller:

•Communicates with scientists including coordination of high-level goals

•Decomposes high-level goals into detailed time lines

•Negotiates detailed schedules with the system level planner and determines science data downlink priorities

•Implements relative science priorities of all activities

•Communicates with system level autonomy and fault software

•Plans around instrument anomalies or faults

•Resumes the investigation after a real-time redirection

•Resolves conflicts between competing science goals and allocates instrument resources

•Supports up to 5 simultaneous investigations and resolves resource conflicts

•In addition to the on-board capability, a ground science development environment to enable scientists to generate, test and load science-observing programs (example architecture is depicted in Figure A2-3)

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Science Processing (Cont)

The Local Instrument functionality: The controller interfaces with the science executive and directs each individual instrument to execute the time lines that were created by the decomposition of the high level goals. The local software includes instrument operation rules, command models, instrument fault detection diagnosis, and recovery software that monitors and responds to anomalies in the instruments.

(2) The Science Recognizer orchestrates responses to opportunistic science events in near real time. (e.g., gamma ray burst), and makes improvements to the investigation current agenda:

Capability metrics are:

- The coverage of the system (i.e., the different kinds of missions to which it applies)
- Ease for composing and inserting a new on-board science-processing element
- The flexibility of the system for reconfiguration
- The effort required to reuse the system to a new mission
- Quality of science data monitoring, including the activity level of the object for recognizers of unexpected phenomena

b. **System-Level Autonomy Software** for High-Level Commanding, and Planning/Scheduling and Sequence Generation. This software includes:

- An on-board system capable of operating missions such as GLAST, SOHO, HST, or FUSE autonomously without input from ground controllers for at least one month is solicited
- The system shall be capable of performing two or more complex goal-oriented tasks while autonomously resolving resource contention
- The autonomy system shall be able to interpret high-level goal-oriented commands (e.g., perform sky survey looking for stars meeting pre-defined criteria or observe a collection of objects--other examples include use or ignore a particular ground station, perform sensor calibration, etc.)
- The autonomy system shall be capable of providing a safe environment for the science investigation

The capability metrics for this area include:

- The effort required to reuse the system for a new mission
- The effort required to maintain the system on orbit

c. **System-Level Autonomy Enabler** for Model-based fault detection, diagnosis, and recovery.

- Software systems for on-board fault detection, diagnosis and recovery.
- On-board trending, analysis and failure detection and prediction systems.

The capability metrics for this area include:

- The fault coverage of the system
- The effort required to reconfigure the system to a new mission
- The effort required to maintain the system on orbit

d. **Autonomy Enabler for Subsystems** including Attitude control, Power, Thermal, Data management. The subsystem autonomy solicited includes:

Each of these advanced subsystems shall seamlessly support the mission and science autonomy systems. Each subsystem and possibly each sensor shall have its own component of the failure detection, prediction, diagnosis and recovery system. For example the gyro executive might monitor the gyros and provide information to the high level trending system on their performance. Failures of specific gyros caught at this level would result in notification messages being sent to the system. For example if a particular gyro is removed from service and replaced with anotherr, a calibration sequence might be required. This would in turn require the science investigation to be suspended.

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e. **Hardware Concepts** supporting breakthrough on-board science processing. Novel concepts for supporting high capacity on-board computing are solicited for validation on this mission. A reconfigurable hardware computing element to support image and signal processing is solicited.

Any hardware proposed should meet NMP guidelines:

- Breakthrough/Enabling
- Require flight validation